

# DIS97

Chicago, Illinois, USA

April 14-18, 1997

## INELASTIC AND ELASTIC $J/\Psi$ PRODUCTION AT HERA

Armin Wegner

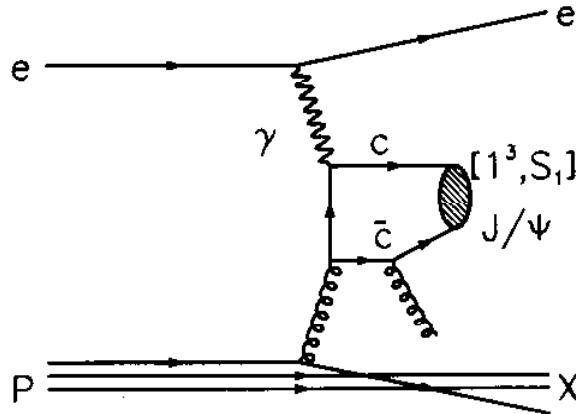
MPI für Physik München  
for the H1 Collaboration



- introduction
- inelastic  $J/\Psi$  production
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- conclusion

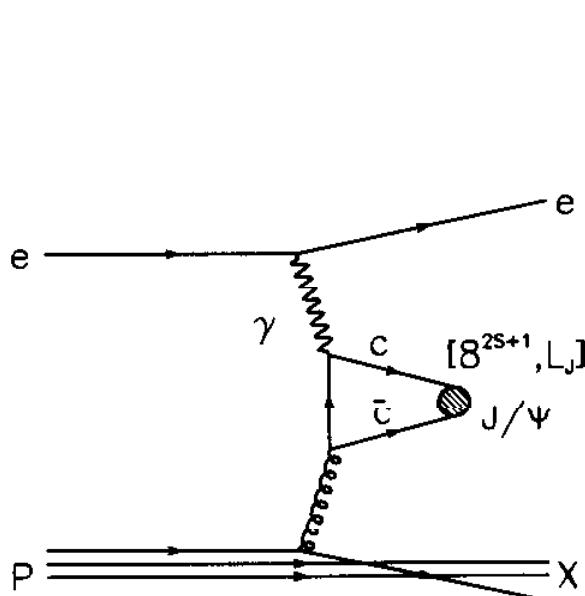
# introduction

## inelastic $J/\Psi$ production



color-singlet model (CS)

- in the CS model a perturbative gluon is radiated to form a colorless  $c\bar{c}$  state
- $\sigma \sim \alpha_s^2 g(x)$  in CS model
- $\Rightarrow$  direct measurement of  $g(x)$



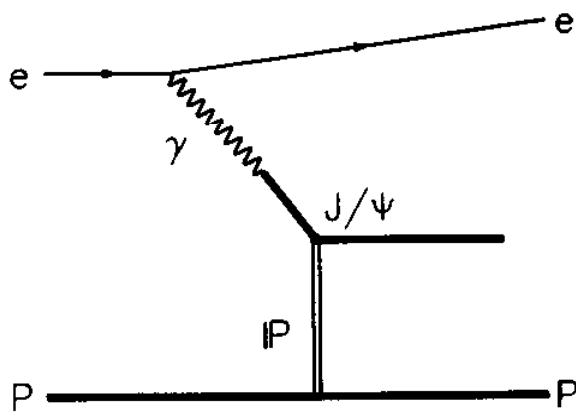
color-octet model (CO)

- in the CO model the  $c\bar{c}$  pair is produced in a color-octet state followed by non-perturbative emission of gluons
- long-distance matrix elements fitted to Tevatron data
- $\Rightarrow$  test of color-octet mechanism at HERA

Inertness gives hard scale for pQCD [i.e.  $Q^2 \approx m_c^2$ ]  
contributions from fragmentation, resolved production and  $b$  decays  
are expected to be small in the kinematic region studied so far

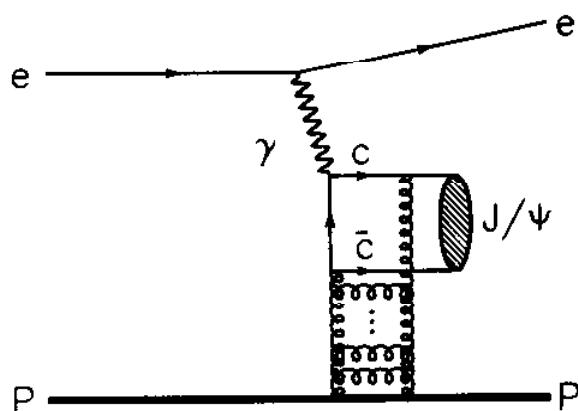
## elastic $J/\Psi$ production

VDM and Regge model



- soft process:
- diffractive production
- slow rise of  $\sigma(W_{\gamma p})$  ( $\propto W^{0.32}$ )
- $d\sigma/d|t| \propto \exp(bt)$
- $b$  rises with  $W_{\gamma p}$ :  
$$b = b_0 + 2\alpha' \ln(W_{\gamma p}/W_0)^2$$

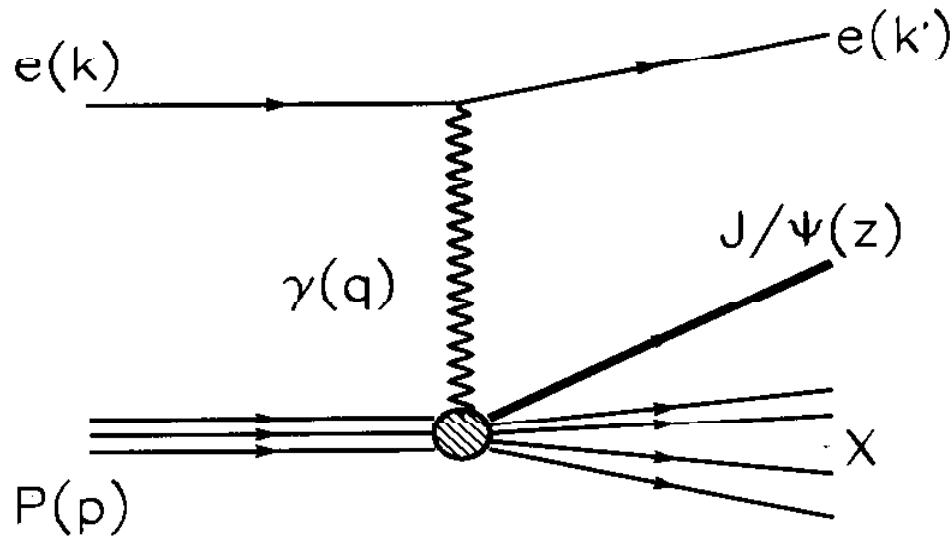
pQCD motivated models



- hard process:
- Ryskin:  $\sigma_{\gamma p} \propto \alpha_s^2 f(x, \mu)^2$   
with  $\mu = \frac{Q^2 + M_V^2}{4}$   
and  $x = \frac{Q^2 + M_V^2}{W_{\gamma p}^2}$
- NLO contributions calculated
- charm mass gives hard scale for pQCD

⇒ study transition region from soft to hard physics

## Kinematic Variables



$$Q^2 = -q^2 = -(k - k')^2 \quad (\approx 0 \text{ for photoproduction})$$

$$x = \frac{Q^2}{2P \cdot q} \quad y = \frac{P_p \cdot q}{P_p \cdot k}$$

$$W_{\gamma p}^2 = (q + P)^2 \approx ys$$

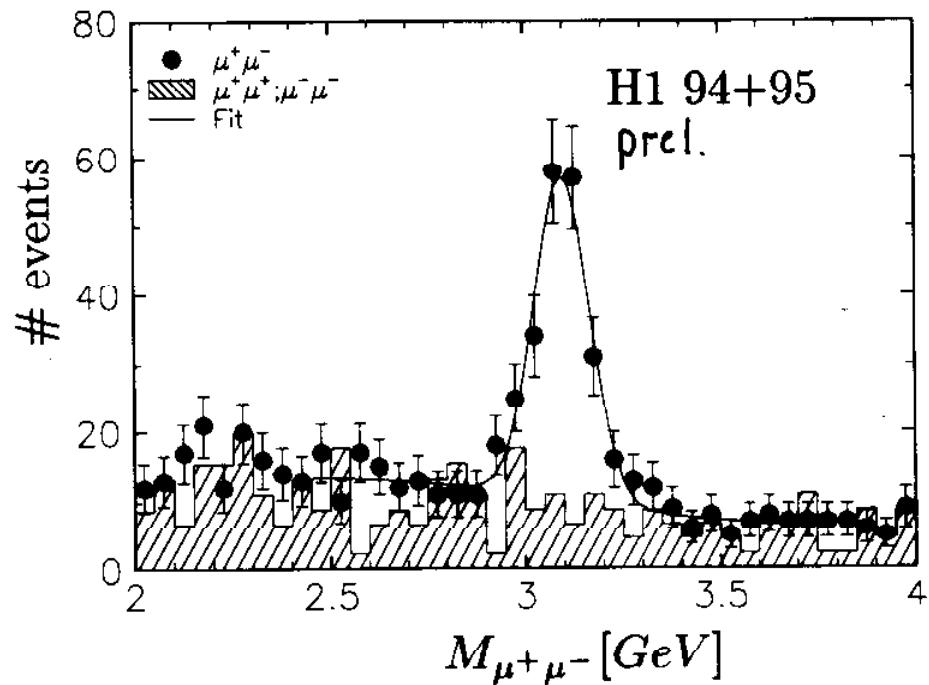
$$z = \frac{P_p \cdot P_\Psi}{P_p \cdot q} \quad (= \frac{E_\Psi^*}{E_\gamma^*} \text{ in Proton rest frame})$$

$$t = (P_p - P_X)^2$$

$$x_g = \frac{1}{ys} \left( \frac{(p^*)_{t,\Psi}^2}{z(1-z)} + \frac{m_\Psi^2}{z} + Q^2 \right)$$

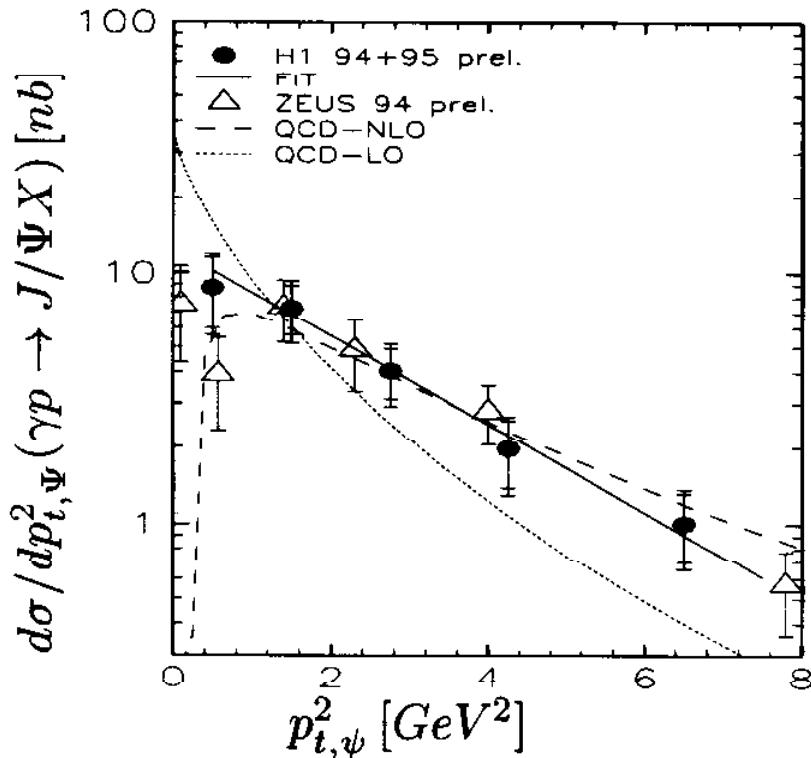
# Inelastic $J/\Psi$ Production

## events selection



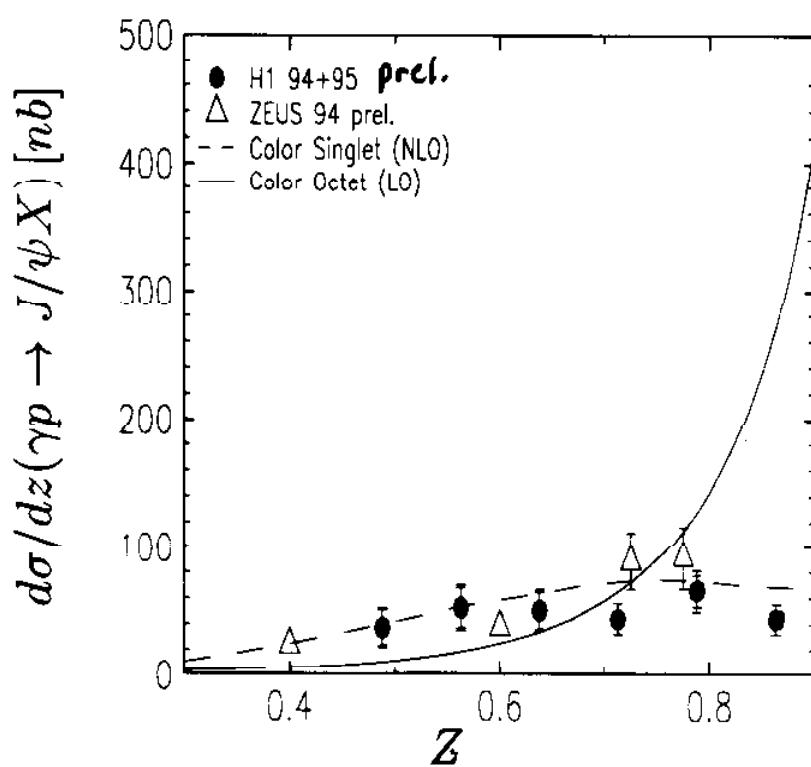
- $J/\Psi$  tagged from its decay into  $\mu^+\mu^-$
- muons measured in central drift chamber
- muons identified in LAr and/or muon detector
- $0.9 > z > 0.45$  to exclude diffractive contributions and to reject events from resolved photon production

## comparison to NLO calculations (M. Krämer)



$p_t^2, \psi$  for  $z < 0.8$

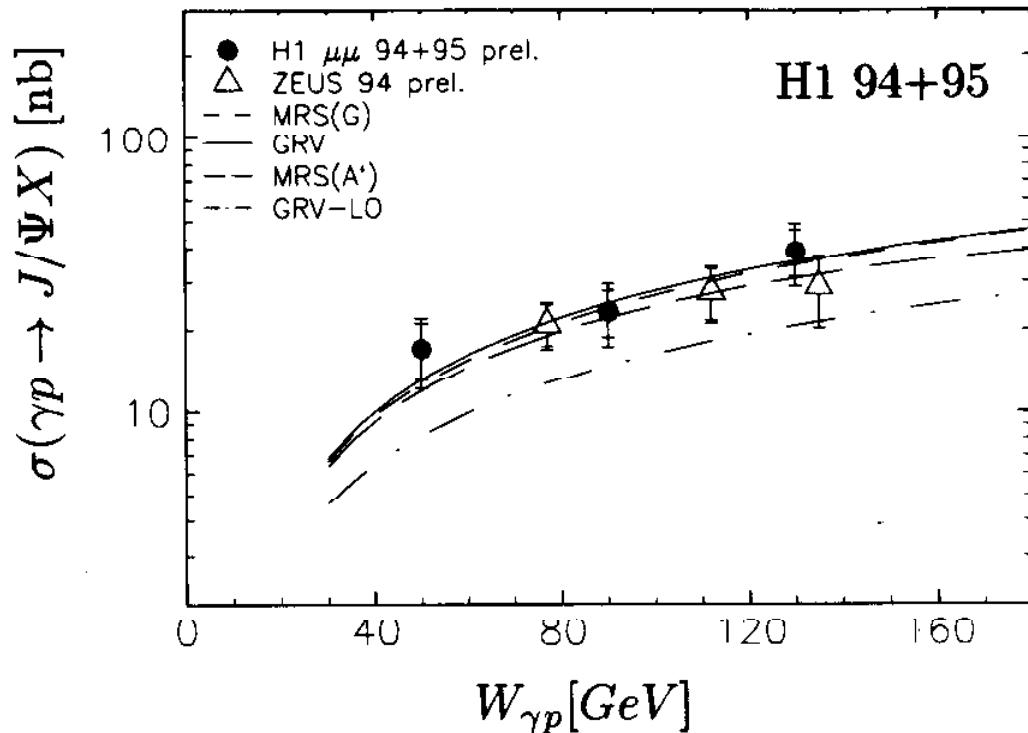
- data are well described by NLO calculations for  $p_t^2 > 1 \text{ GeV}^2$
- LO calculations steeper than data



$z$  for  $p_t^2, \psi > 1 \text{ GeV}^2$

- color octet relevant for high  $z$  (Krämer,Cacciari)
- normalisation from Tevatron data
- no evidence for large color octet contribution at H1

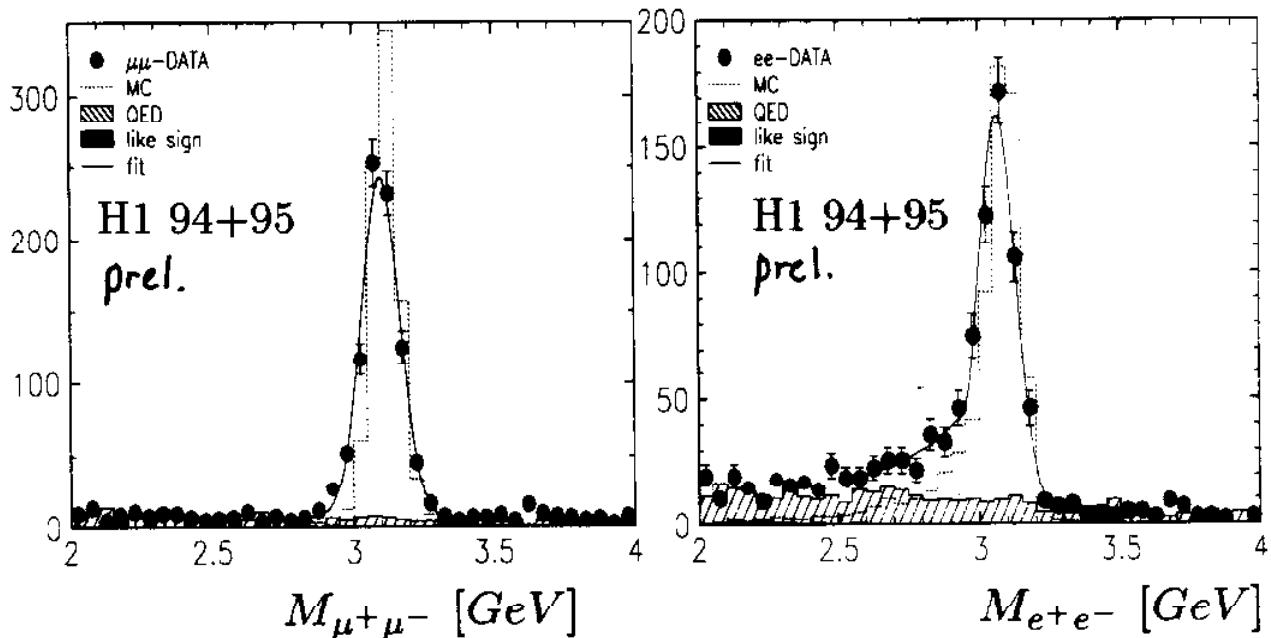
## cross section vs. $W_{\gamma p}$



- cross section rises with  $W_{\gamma p}$
- NLO calculation fit data in shape  
normalisation correct for  $m_c = 1.4\text{GeV}$ ,  $\mu = \sqrt{2}m_c$   
and  $\Lambda_{QCD} = 0.3\text{GeV}$
- sensitivity to  $g(x)$  low within cuts
- extraction of gluon density
  - LO extraction of  $g(x)$  possible but questionable because  $x_g$  is sensitive to  $p_t$  (see formula)
  - direct measurement of  $g(x)$  needs NLO calculation differential in  $x_g$

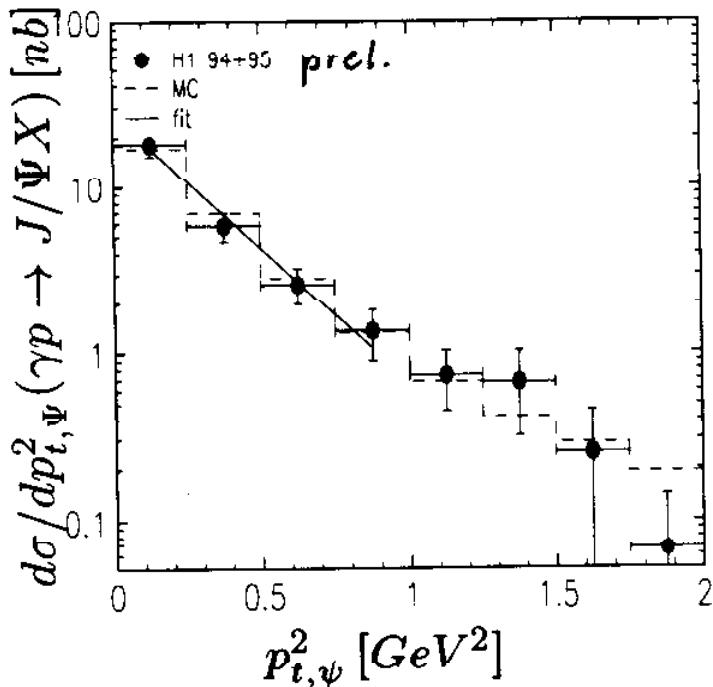
# Elastic $J/\Psi$ Production

## events selection



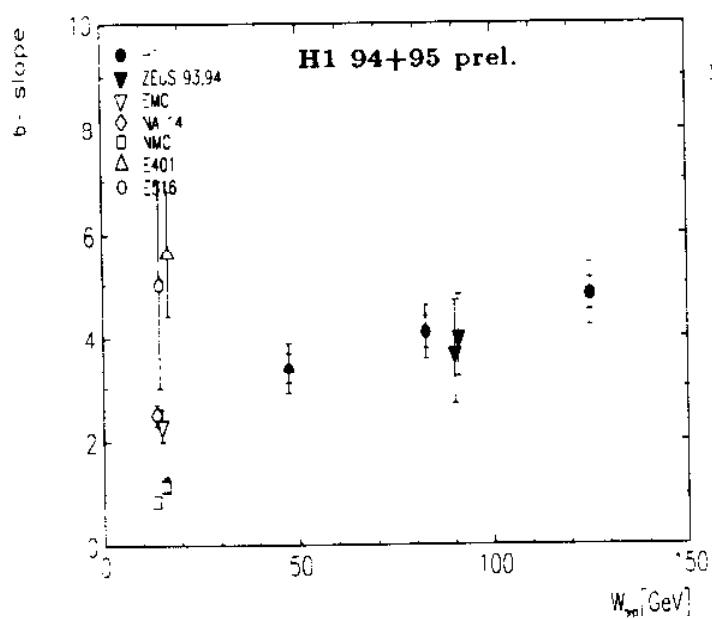
- $J/\Psi$  tagged from its decay into  $\mu^+\mu^-$  or  $e^+e^-$
- $\vec{p}_{\mu,e}$  measured in central drift chamber or BEMC ( $J/\Psi \rightarrow e^+e^-$ )
- muons identified in LAr and/or muon detector
- electrons identified in LAr or BEMC (1994)
- $z > 0.9$  to select diffractive contributions
- forward cuts against proton dissociation  
no signal (above noise) in forward detectors:  
proton tagger (+24 m), forward muon system  
and forward part of LAr
- proton dissociation cross section measured separately (not shown here)

## t distribution



$$p_t^2 \simeq -t \text{ for } Q^2 \simeq 0$$

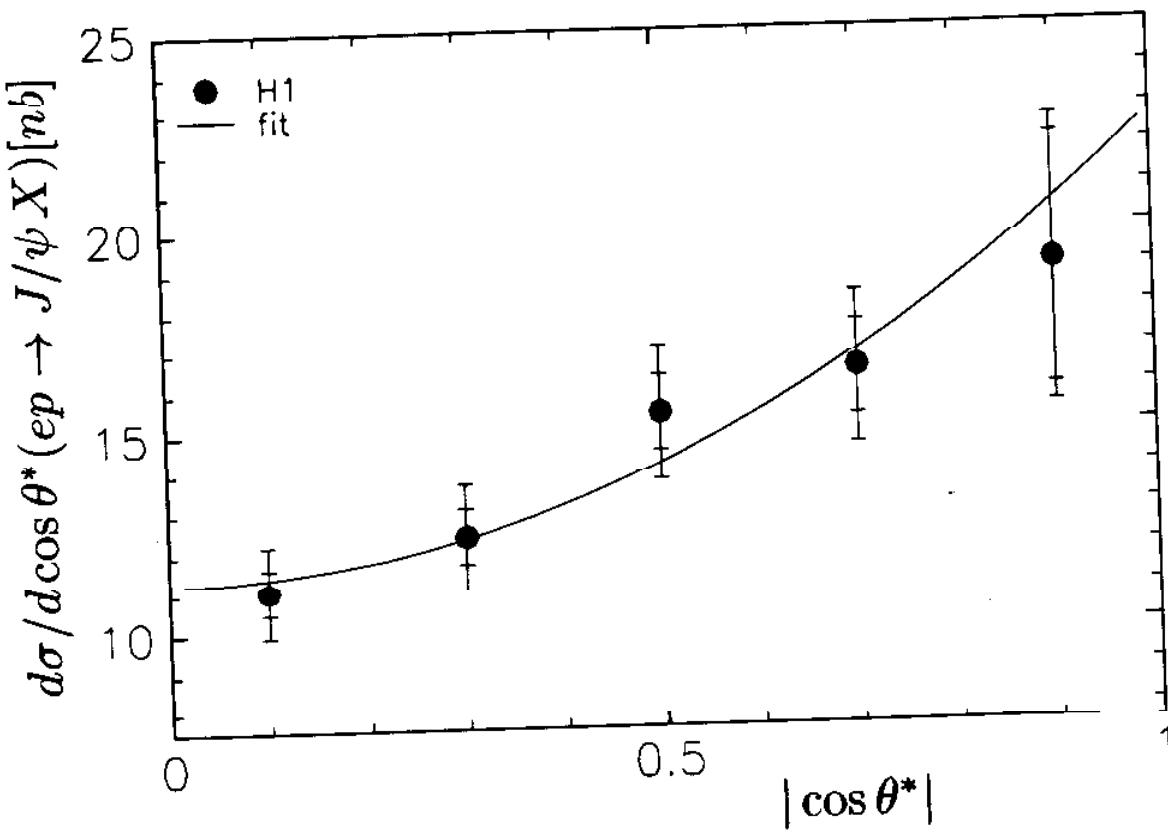
- t-distribution exponential ( $\propto \exp(bt)$ )
- $b = 4.1 \pm 0.2 \pm 0.2 \pm 0.4$  for  $30 < W_{\gamma p} < 150 GeV$



shrinkage?

- fit to  $b = b_0 + 2\alpha' \ln(W_{\gamma p}/W_0)^2$  gives:
- $\alpha' = 0.36 \pm 0.21 GeV^{-2}$   
H1 only

## decay angular distribution



decay angle of  $J/\Psi$  in  $J/\Psi$  rest frame ( $\Theta^*$ )

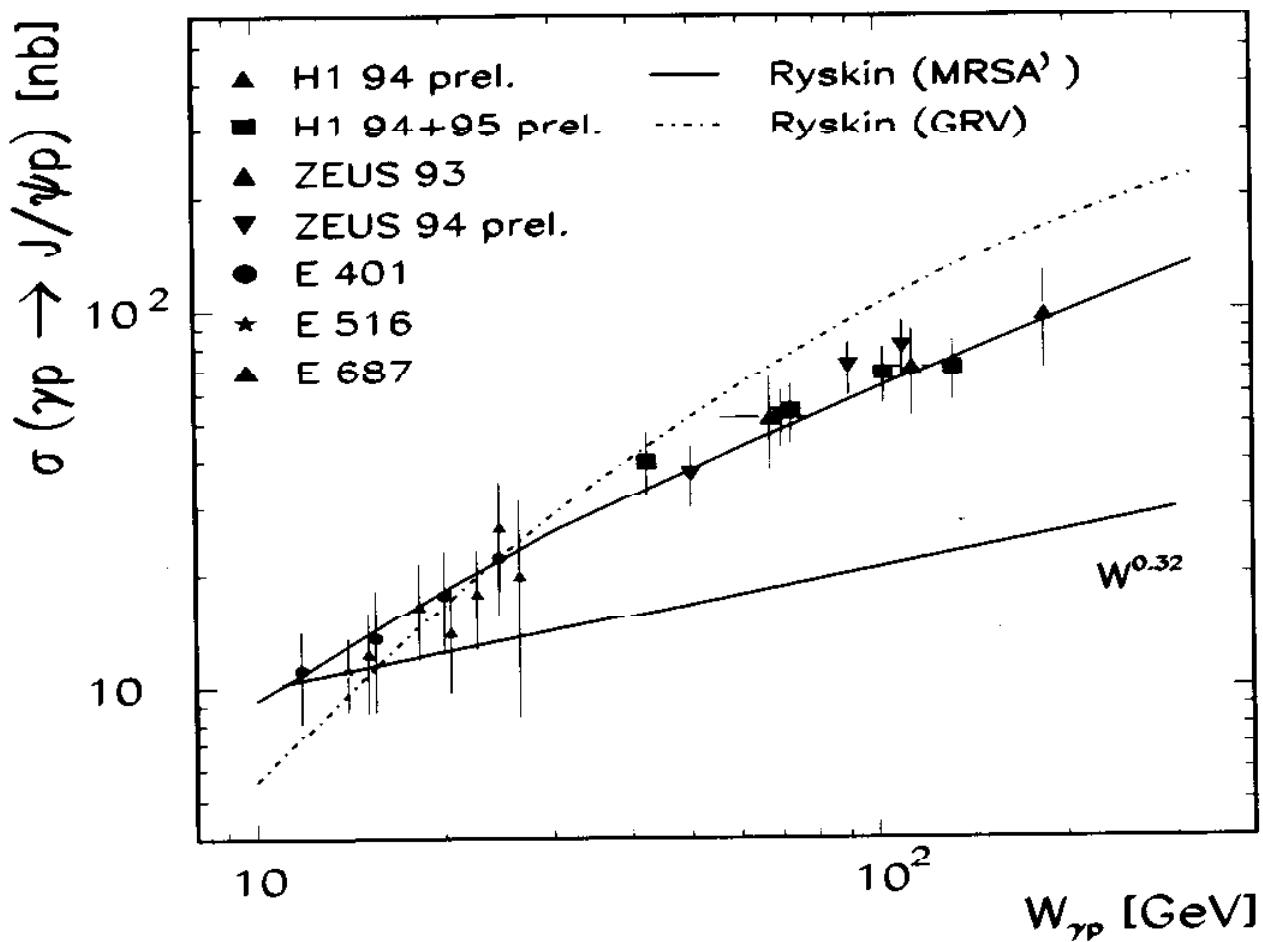
- $\frac{d\sigma}{d \cos \theta^*} \propto \frac{3}{8} (1 + r_{00}^{04} + (1 - 3r_{00}^{04}) \cos^2 \theta^*)$

$$R = \sigma_L / \sigma_T = \left(\frac{1}{\epsilon}\right) \frac{r_{00}^{04}}{1 - r_{00}^{04}} \quad (\epsilon \simeq 1)$$

- from fit:  $r_{00}^{04} = -0.2 \pm 0.2$

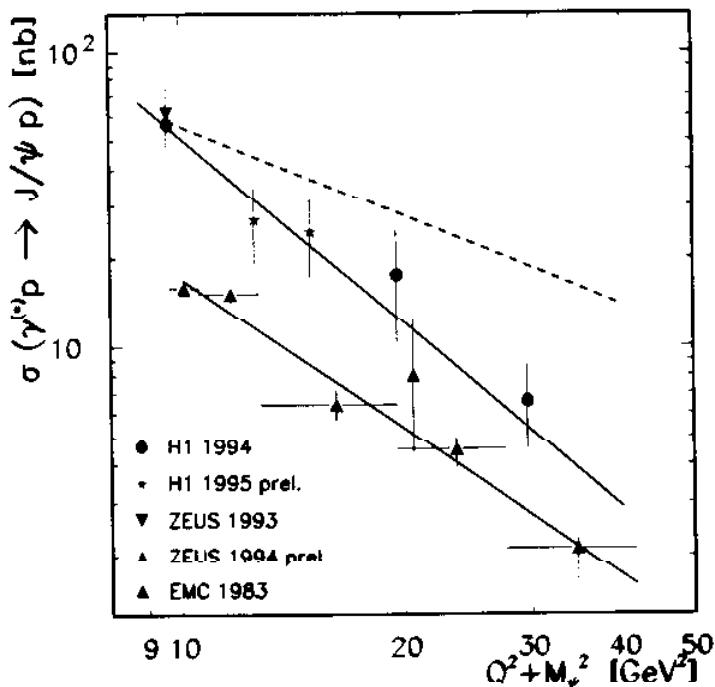
- consistent with SCHC

cross section vs.  $W_{\gamma p}$



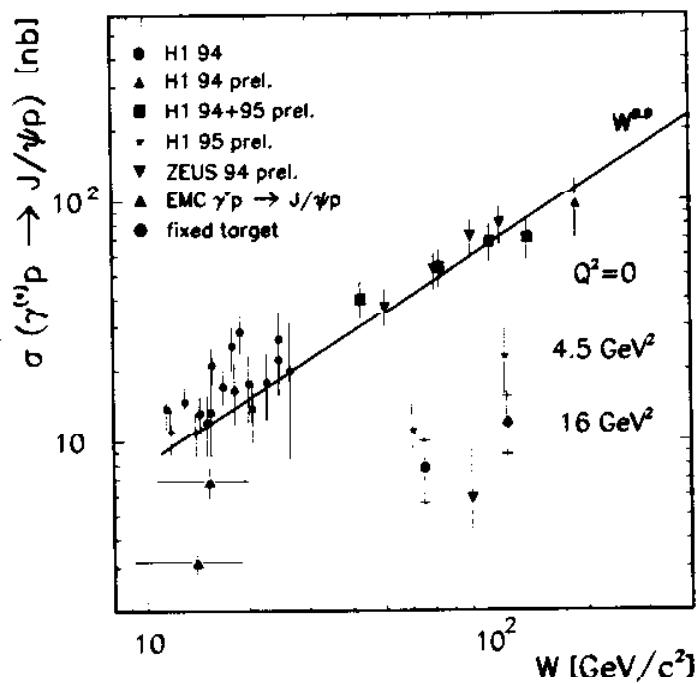
- slow rise of cross section ( $\sigma_{\gamma p} \propto W_{\gamma p}^{0.22-0.32}$ ) excluded
- fit to HERA data gives:
  - $\sigma_{\gamma p} \propto W_{\gamma p}^{0.9}$  including fixed target data
  - $\sigma_{\gamma p} \propto W_{\gamma p}^{0.6}$  HERA only
- the Ryskin model using a scale of  $m_\Psi^2/4$  with MRS(A') parametrisation of the gluon density agrees well with the data

## Elastic $J/\Psi$ Production in DIS



cross section as function  
of  $Q^2 + m_\Psi^2$

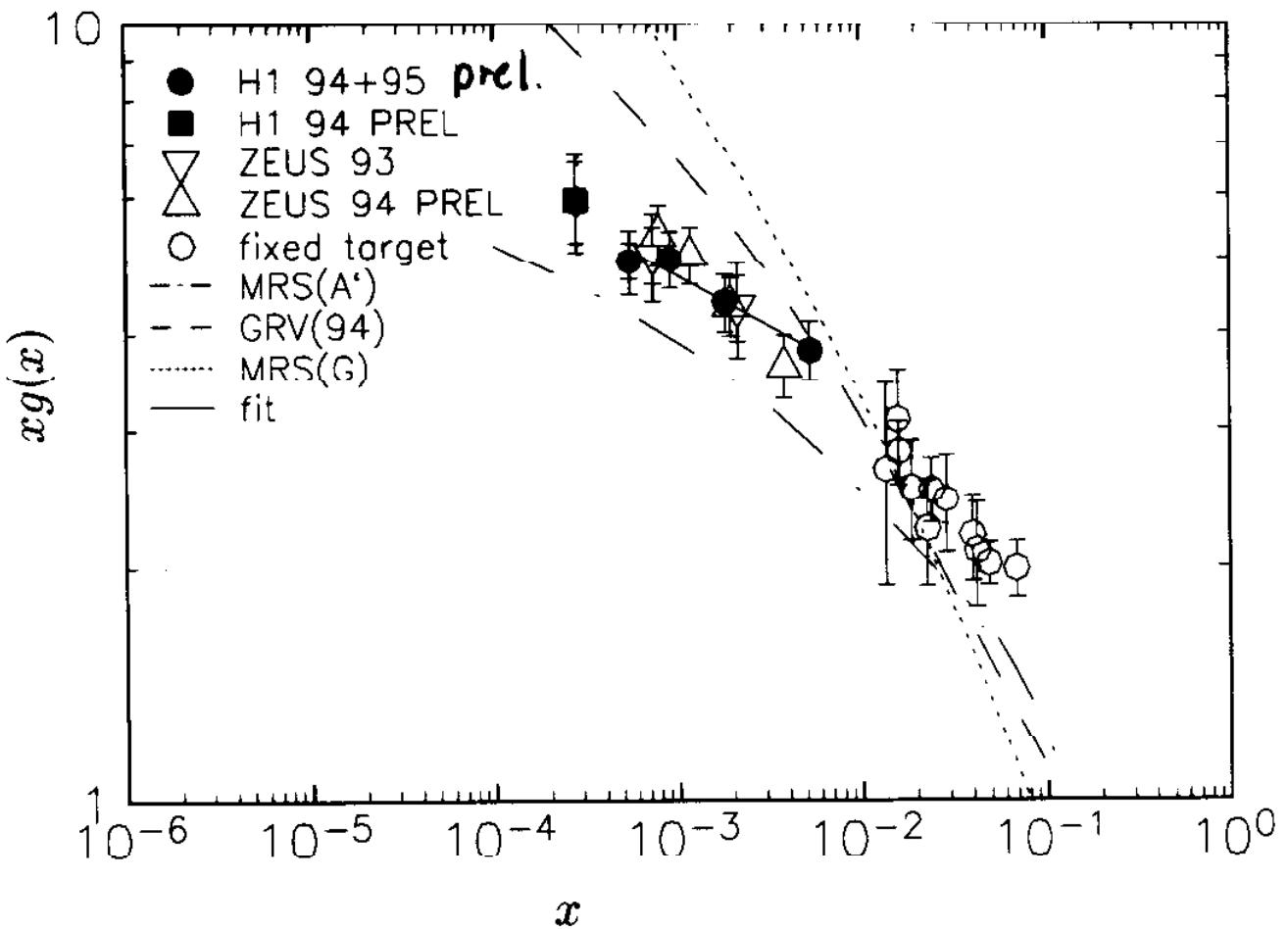
- $\sigma(\gamma p \rightarrow J/\Psi p) \propto 1/(Q^2 + m_\Psi^2)^n$
- fit:  $n \simeq 2$



cross section as function of  
 $W_{\gamma p}$

- similar rise with  $W_{\gamma p}$  as  
in photoproduction

## gluon density from the Ryskin model



- use Ryskin model (LO) to extract gluon density
- $xg(x, \bar{Q}^2)^2 = \frac{48\alpha\bar{Q}^8}{\Gamma_{ee}m_\psi^3\pi^3\alpha_S^2} b \cdot \sigma(\gamma p \rightarrow \psi p) \left(1 + \frac{Q^2}{m_\psi}\right)^{-1}$
- with:
$$x = \frac{4\bar{Q}^2}{W_{\gamma p}^2}$$

$$\bar{Q}^2 = \frac{(Q^2 + m_\psi^2)}{4}$$
- in the Ryskin model the MRS(A') parametrisation of the gluon density agrees well with the data

## Conclusion

- inelastic  $J/\Psi$  production
  - inelastic  $J/\Psi$  production is well described by color singlet model in NLO
  - no indication of large color octet contributions is seen
- elastic  $J/\Psi$  production
  - data show exponential  $t$  slope and agree with s-channel helicity conservation
  - cross section increases much faster than expected in “soft” models with pomeron exchange
  - Ryskin model describes the data with MRSA’ parametrisation of the gluon density